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(54) Methods and circuit for the recognition of colours

(57) The circuit arrangement includes a source of light 3, 4 of known spectrum composition for illumination of the coloured area 1 to be examined, and three opto-electronic transducers 14, 15, 16 for detection of the reflected or transmitted intensities of three primary colours as colour components. A colour recognition memory 28 is connected via "A/D" transducers 19, 20, 21 to transducers 14, 15, 16 and intended for reception of identification symbols, said memory being addressable by means of digitalised colour components. A sample memory 36 is connected to an input stage 35 for allocating identification symbols and to the "A/D" transducers 19, 20, 21 for storage of a specimen list compiled from the colour components of the specimen points and the co-ordinated identification symbols. An address control system 37 is connected to memories 28 and 36 for calling colour components and for selection of the addresses of memories 36 and 28, and a counter circuit 38 is connected to the memory 36, the address control system 37 and memory 28 and intended to ascertain the identification symbols from the colour components called and from the sample list.

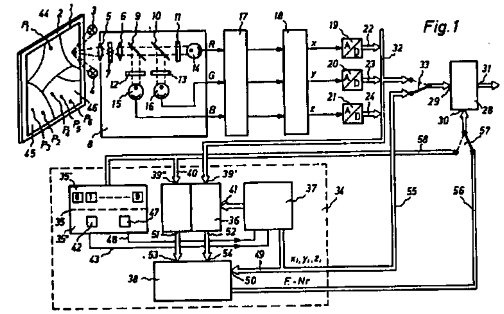
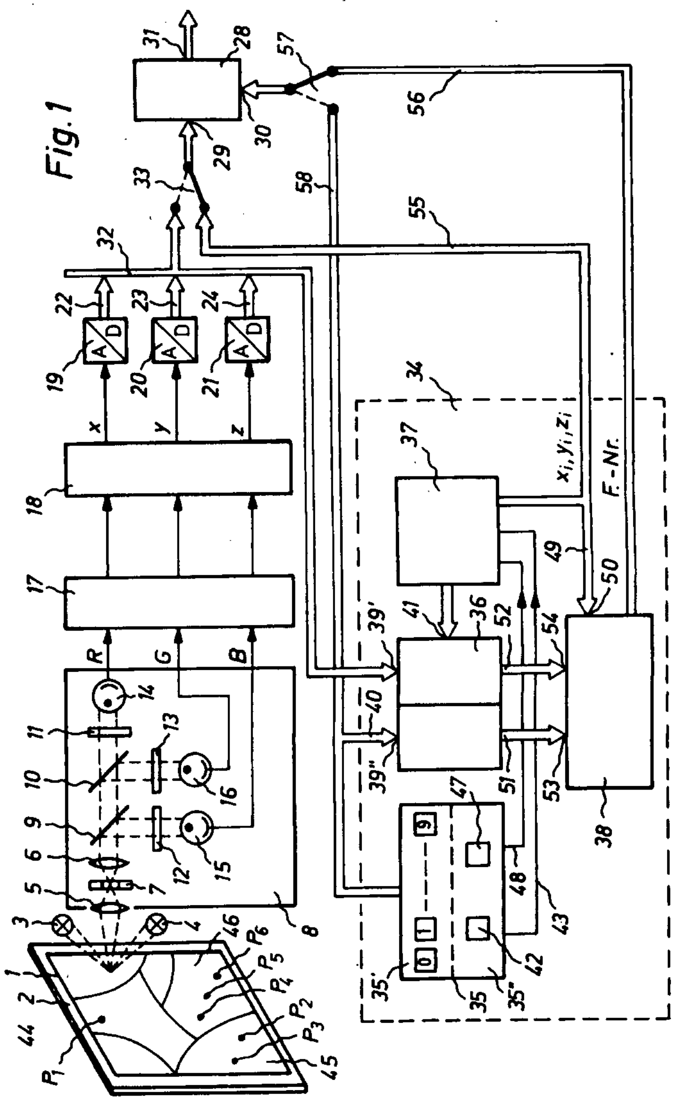


Fig.1

The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

Fig. 1



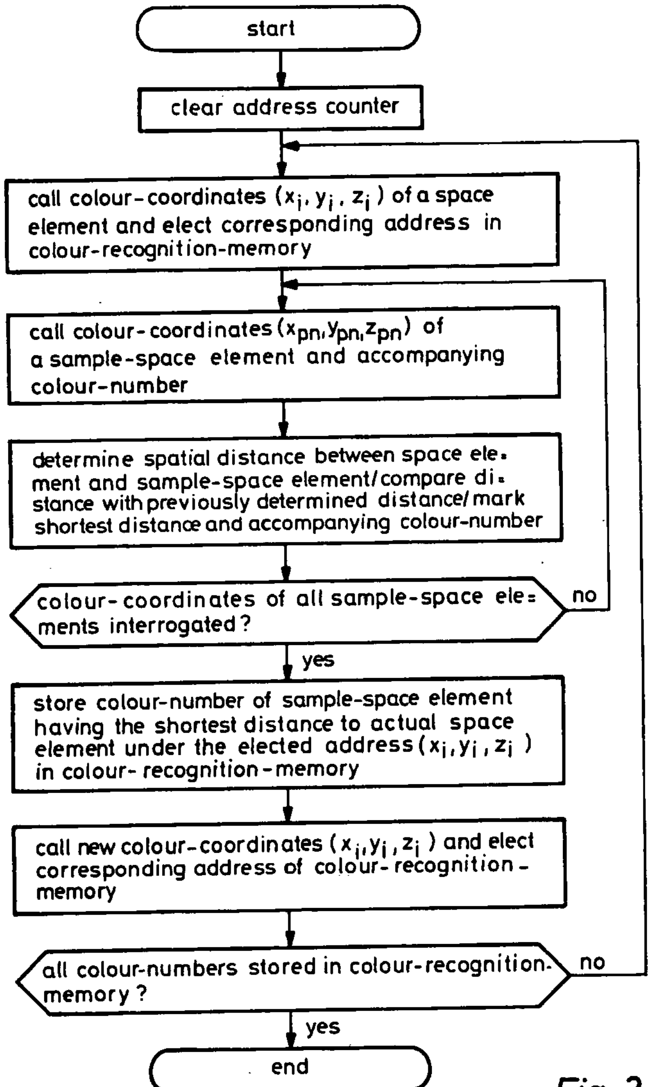


Fig. 2

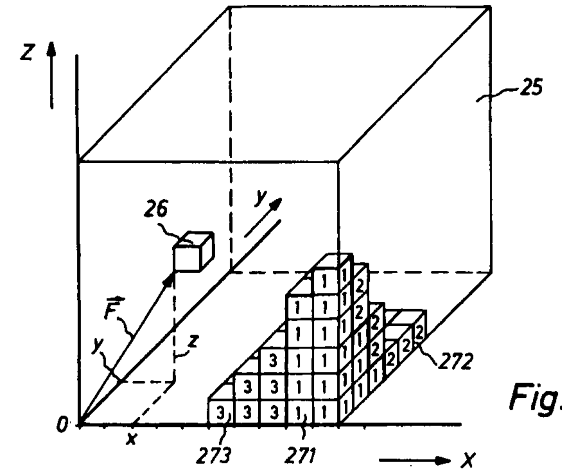


Fig. 3

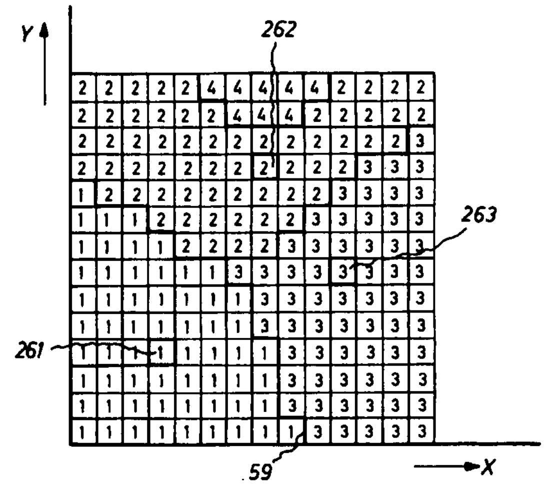


Fig. 5

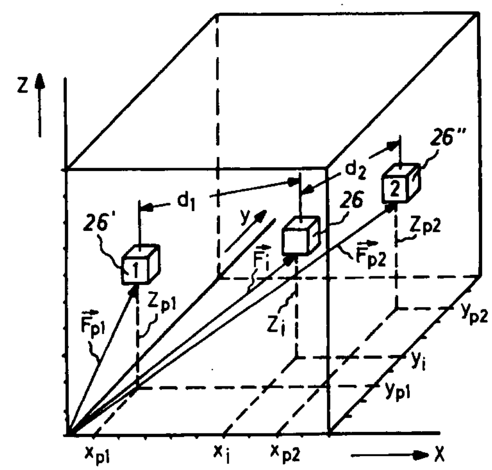
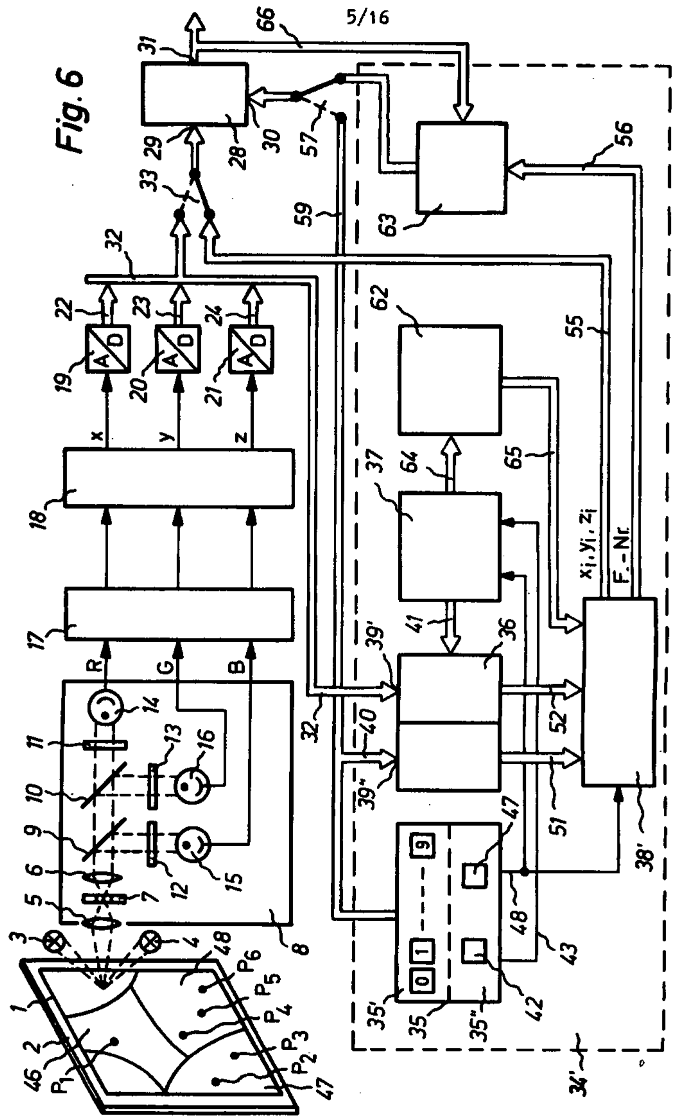

Z
X
26'
26
26''
d1
d2
y
1
2
Fp1
Fi
Fp2
Zp1
Zi
Zp2
yp2
yi
yp1
xp1
xi
xp2

Fig. 4

Fig. 6


R
G
B
x
y
z
A
D
xi, yi, zi
F.-Nr.
P1
P2
P3
P4
P5
P6
0
1
9

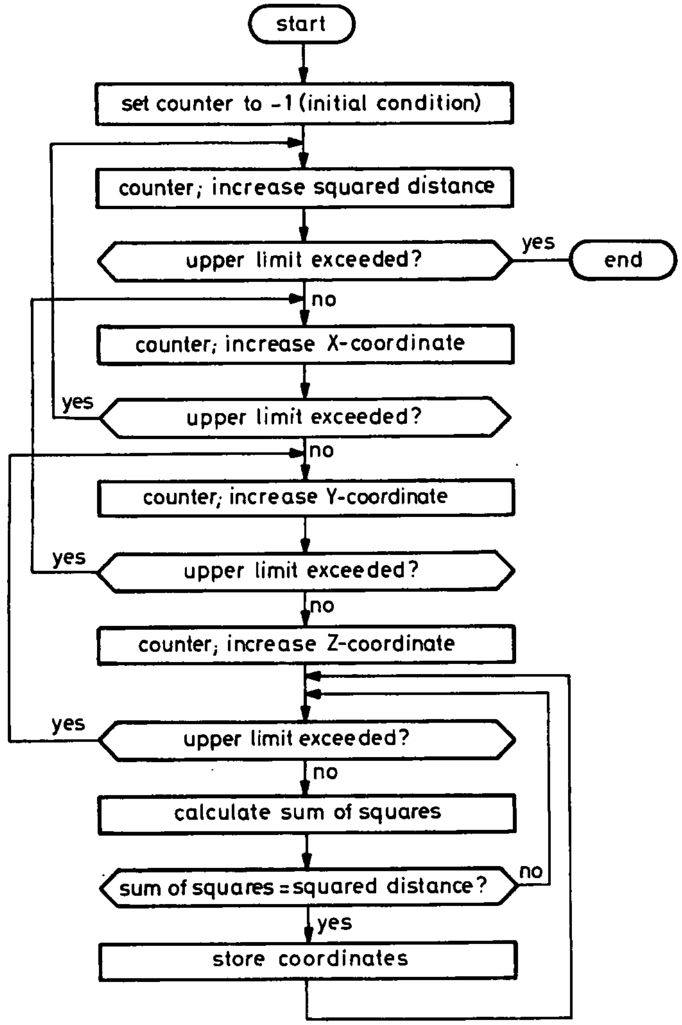


Fig. 7

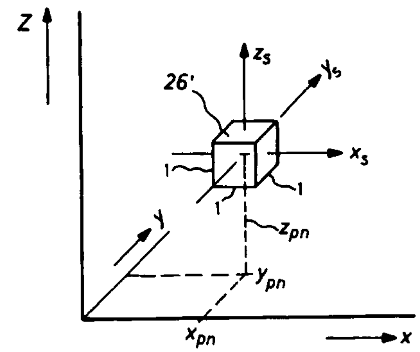


Fig. 8a

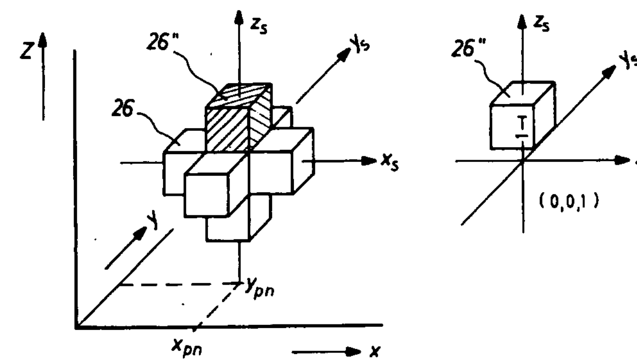


Fig. 8b

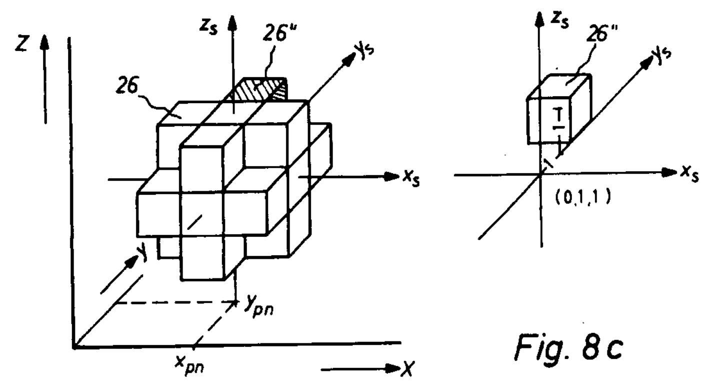


Fig. 8c

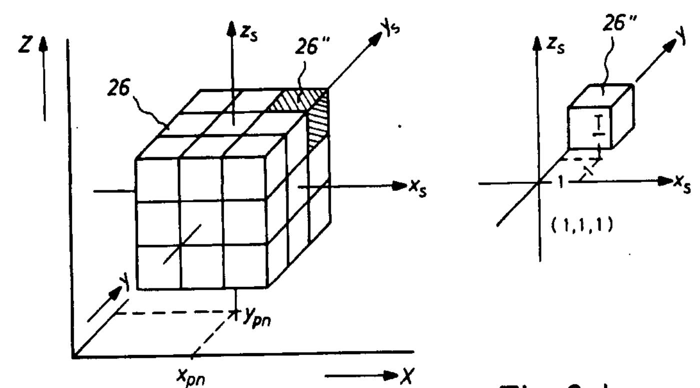


Fig. 8d

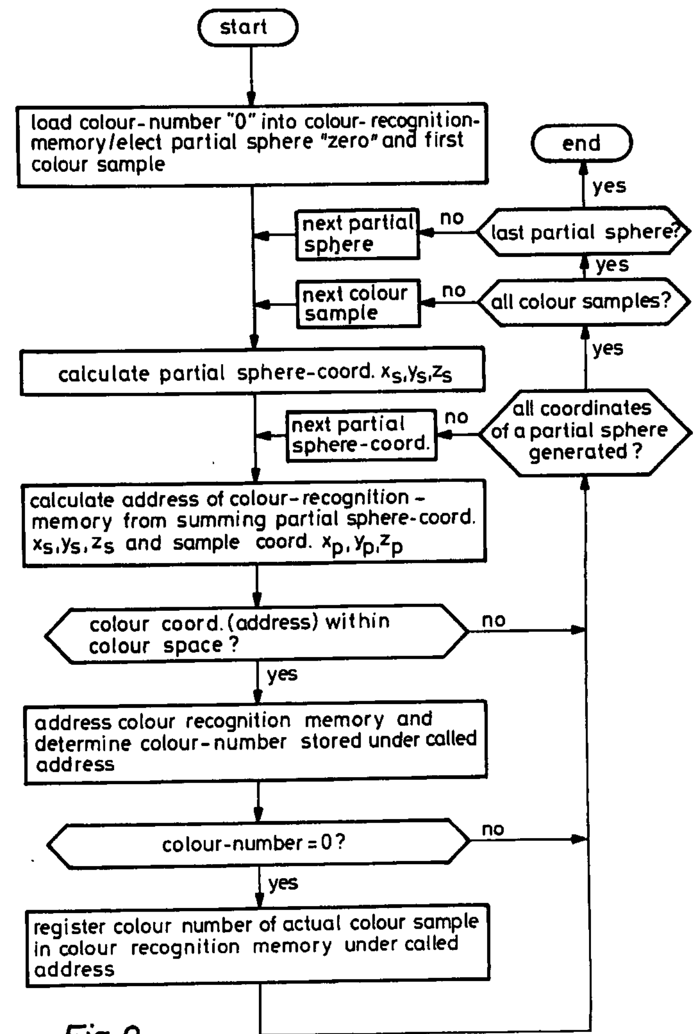


Fig. 9

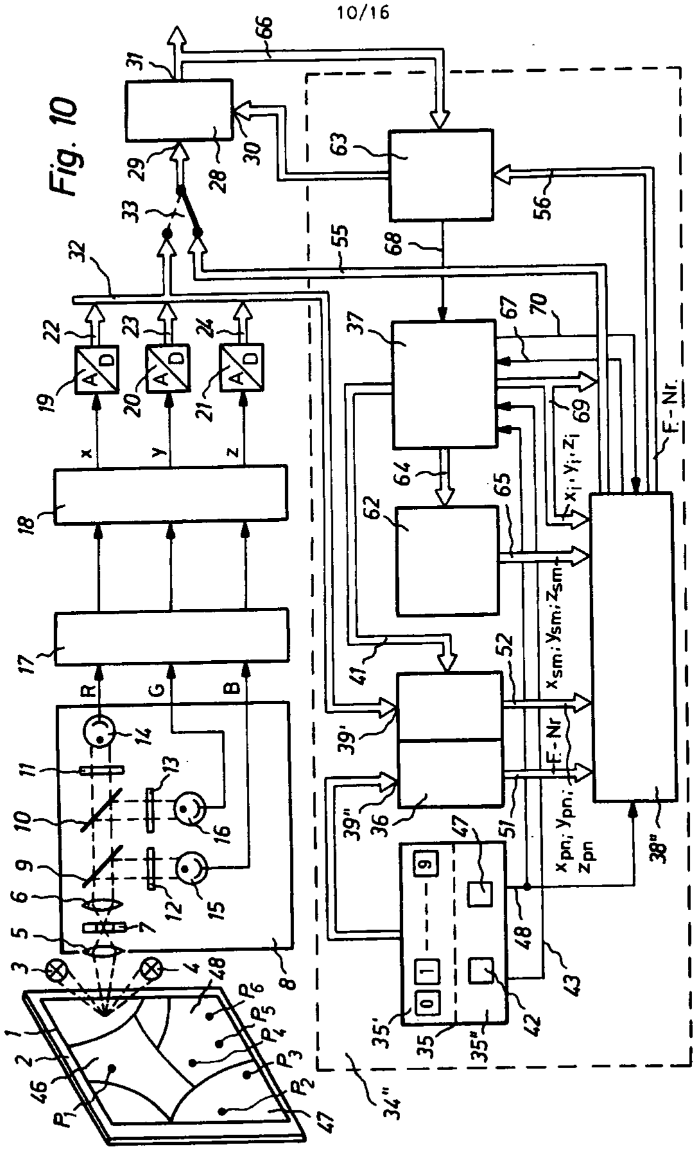

R
G
B
x
y
z
A D
F-Nr.
$x_{sm}; y_{sm}; z_{sm}$
$x_i; y_i; z_i$
$x_{pn}; y_{pn}; z_{pn}$
P_1 P_2 P_3 P_4 P_5 P_6

Fig. 10

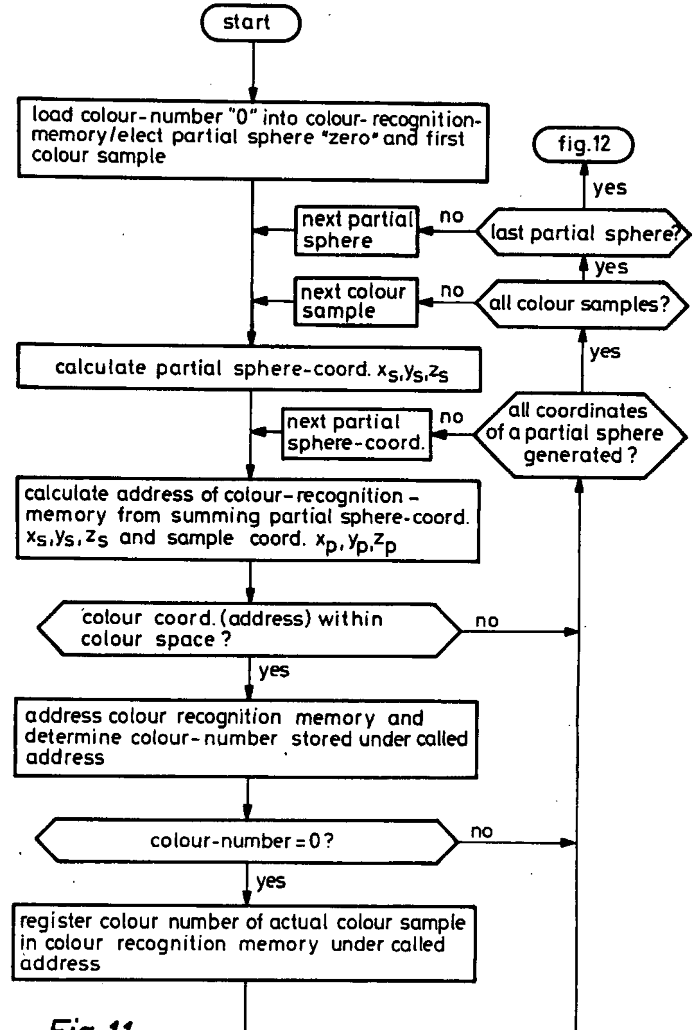

start
load colour-number "0" into colour-recognition-memory/elect partial sphere "zero" and first colour sample
calculate partial sphere-coord. x_s, y_s, z_s
calculate address of colour-recognition-memory from summing partial sphere-coord. x_s, y_s, z_s and sample coord. x_p, y_p, z_p
colour coord. (address) within colour space ?
yes
no
address colour recognition memory and determine colour-number stored under called address
colour-number = 0 ?
yes
no
register colour number of actual colour sample in colour recognition memory under called address
all coordinates of a partial sphere generated ?
no
next partial sphere-coord.
yes
all colour samples?
no
next colour sample
yes
last partial sphere?
no
next partial sphere
yes
fig.12

Fig. 11

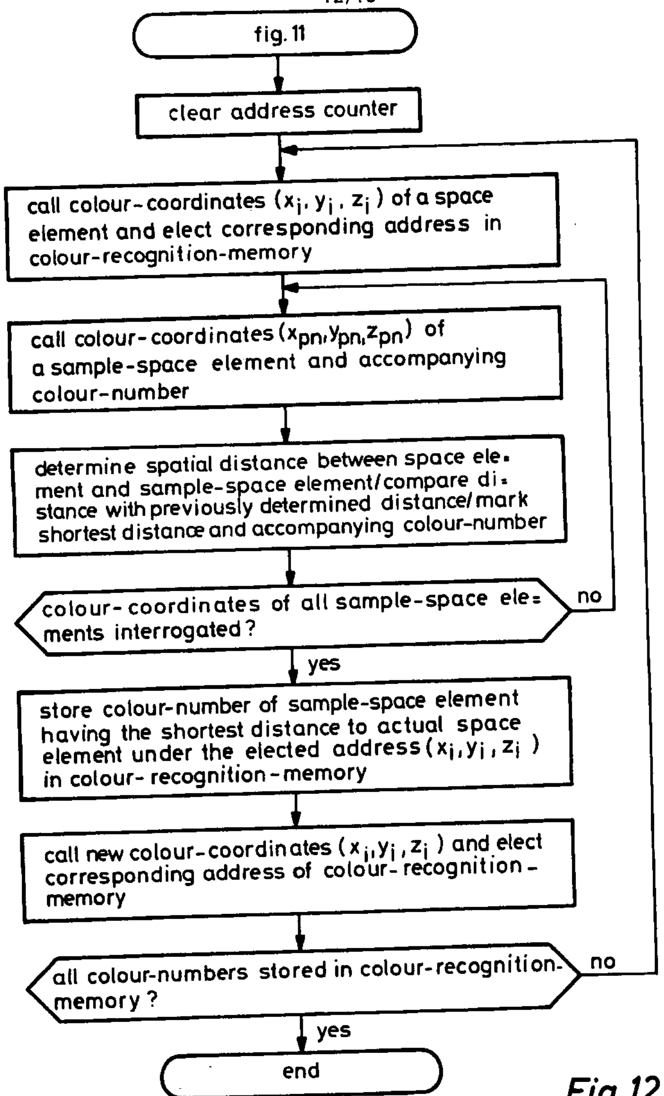


fig. 11
clear address counter
call colour-coordinates (x_i, y_i, z_i) of a space element and elect corresponding address in colour-recognition-memory
call colour-coordinates (x_{pn}, y_{pn}, z_{pn}) of a sample-space element and accompanying colour-number
determine spatial distance between space element and sample-space element/compare distance with previously determined distance/mark shortest distance and accompanying colour-number
colour-coordinates of all sample-space elements interrogated?
no
yes
store colour-number of sample-space element having the shortest distance to actual space element under the elected address (x_i, y_i, z_i) in colour-recognition-memory
call new colour-coordinates (x_i, y_i, z_i) and elect corresponding address of colour-recognition-memory
all colour-numbers stored in colour-recognition-memory?
no
yes
end

Fig.12

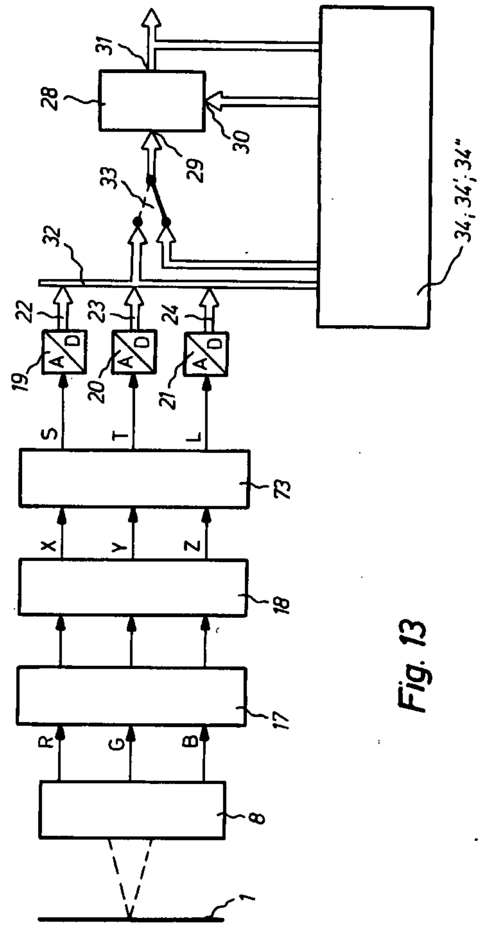

1
8
R
G
B
17
18
X
Y
Z
73
S
T
L
19
20
21
A
D
22
23
24
32
33
29
28
30
31
34; 34'; 34"

Fig. 13

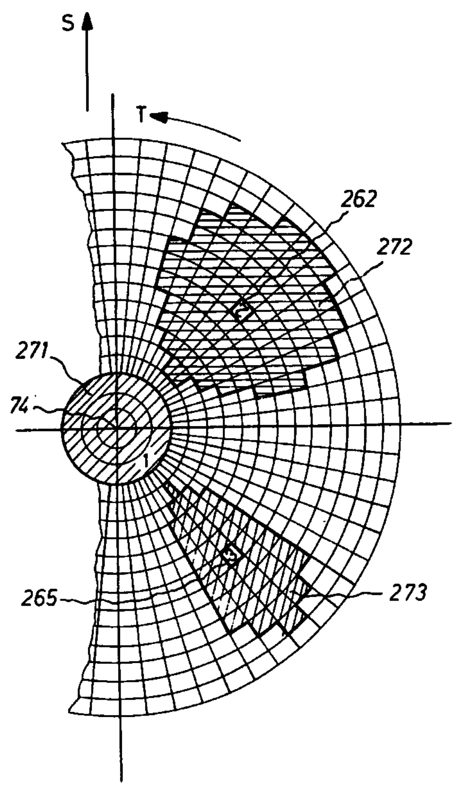

S
T
262
272
271
74
265
273

Fig. 14

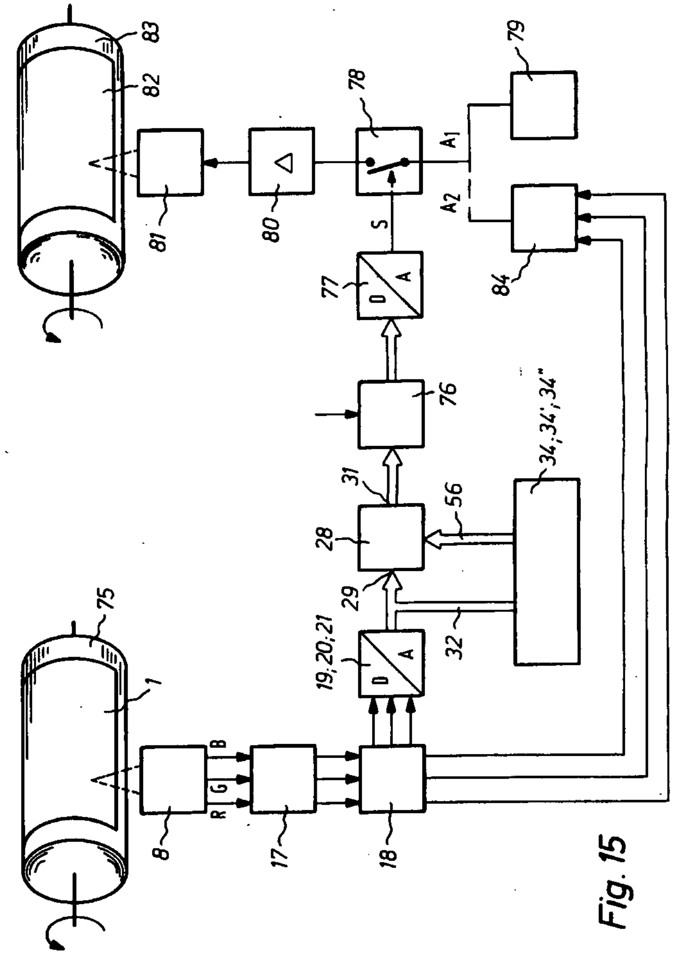

83
82
79
78
A1
A2
S
81
80
77
D
A
84
76
34;34';34"
31
56
28
29
19,20;21
32
75
1
B
G
R
8
17
18

Fig. 15

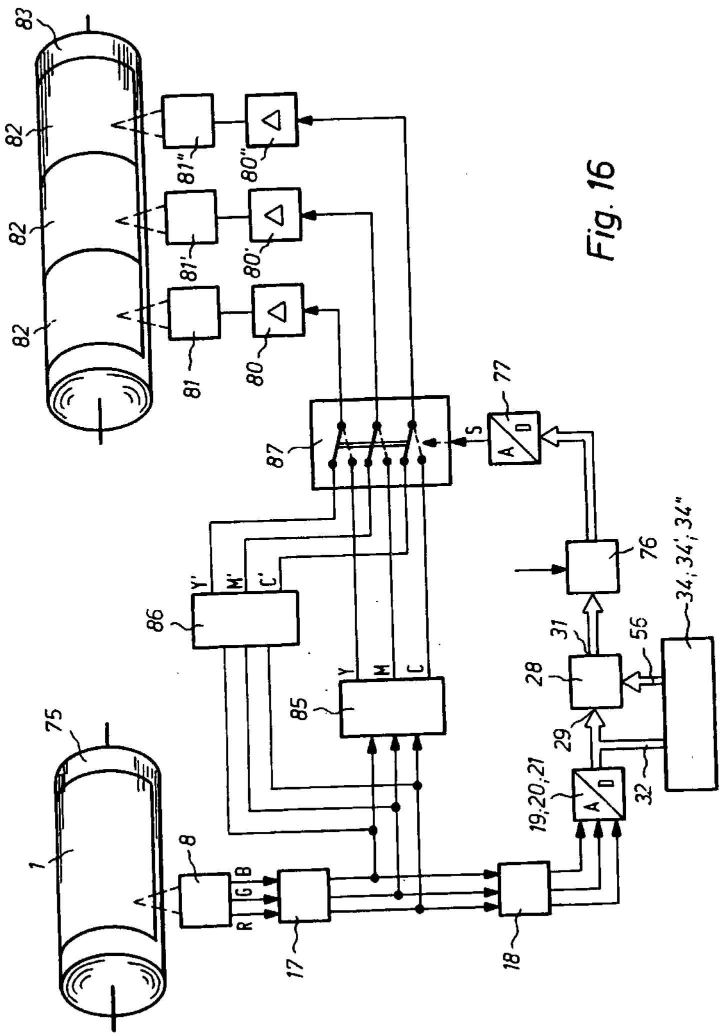


Fig. 16

SPECIFICATION

Improvements in or relating to methods of and circuit arrangements for the recognition of colours

The present invention relates to methods of and circuit arrangements for the recognition of colours in which a coloured surface is illuminated with light having a known spectrum composition and the intensities of three primary colours are measured opto-electrically in the reflected or transmitted light as colour components, which represent the spatial co-ordinates of the colour locations (point of space) in a colour space, and wherein colour recognition spaces are delimited for each colour to be recognised in the colour space and the measured colour components are verified regarding their correspondence to the colour recognition spaces.

The terms "colour originals" are to be taken as denoting pictorial or pattern originals for reproductions, pattern designs for obtaining control data for textile processing machinery, coloured printed matter and in general any coloured area or surface.

A colour measurement triplet representing the chromatic components of the colour or the co-ordinates of the corresponding colour locus in the RGB colour space is engendered for each colour during the trichromatic scanning of coloured originals.

Colour fluctuations or colour deviations occur in the hues of an original, which are intended by the designer on the one hand, but which may on the other hand be caused by the colour tolerances of the commercially obtainable colourations or by an uneven application of colour. These colour fluctuations of the individual colours lie within limited spatial colour ranges which have to be recognised as a colour during colour recognition or colour separation and which consequently have corresponding colour recognition spaces allocated to them in the RGB colour space.

A colour selection circuit then currently determines in which of the pre-arranged colour recognition spaces a colour signal triplet obtained by scanning an original occurs, and indicates the presence of a colour.

Such colour selection circuits are applied, for example in colour scanners for production of colour separations for composite multicolour printing (printing on paper) or for printing for textile, decorative and packaging purposes.

A colour correction which on the one hand makes allowance for the chromometically inadequate quality of the printing colours and with which it is possible on the other hand to modify the editorially required chromatic impression of the reproduction as compared to the original, is performed during the production of colour separations for composite multicolour printing. Apart from a fundamental correction, a complementary selective correction is performed, which is intended to act on quite particular colours. The problem thus arises of selecting the colours which are to be exposed to particular correction, by means of colour selection circuits.

In contradistinction to composite multicolour printing, the colours are mixed prior to the printing operation and then transferred separately on to the printing medium, in the case of textile, decorative and packaging printing. The problem prevails in this case of separating the individual colours of the original by means of a colour selection circuit and of producing a separate colour separation for each colour.

A colour selection circuit is also required in a scanning apparatus for pattern designs for obtaining control data for textile processing machinery. In their case, the purpose equally consists in selecting individual colours from a drawn coloured draft pattern. These colours are then converted into control data and stored on a data carrier as chromatic data.

A colour selection circuit is already known from United States Patent Specification No. 3,210,552, wherein the required boundaries of a colour recognition space are reproduced electronically by adjustable threshold circuits. The correspondence between a colour which is to be identified and the colour recognition space is determined by comparison of the colour mensuration signals with the threshold set up.

The size of the colour recognition space may well be adjusted, but the shape is substantially parallelepipedal.

The known colour selection circuit has the disadvantage that the form of the colour recognition space cannot be adapted in optimum manner to a spatial colour range which is to be separated without enormous circuit complexity, which is why errors occur in colour recognition. Another disadvantage consists in that there is hardly any possibility of adapting the selection circuit to the special circumstances of the original which is to be analysed. The individual adjustment of the thresholds actually proves to be extremely difficult since, as may be imagined, there is no relationship between the colour space on the one hand and the electrical threshold on the other hand. To separate a plurality of colours requires an identical plurality of threshold circuits to be incorporated and adjusted, which is extremely costly and time-consuming.

Another version of colour recognition was disclosed in United States Patent Specification No. 3,012,666 and in German Offenlegungs Specification No. 2,158,758, in which the spatial colour recognition is simplified to a two-dimensional problem. In their case, the colour recognition spaces are delimited by straight lines which are again reproduced by threshold circuits.

It has now been discovered in practice, that these methods do not provide any satisfactory results either, since the reliability of colour recognition is frequently inadequate. In addition, e.g. because of the "banana-shaped" form of the colour recognition spaces in the above mentioned German specification no. 2,158,758 it is difficult to fill the colour space totally with colour recognition spaces, which equally leads to

uncertainty during colour recognition.

It is therefore an object of the invention to eliminate or minimise the said disadvantages and to suggest improved methods and circuit arrangements for recognition or separation of colours, whereby the colour recognition spaces may be adapted to the spatial colour ranges which are to be seperated, thereby securing considerable reliability of recognition.

Accordingly, the invention consists in a method for the recognition of colours, in which a coloured surface is illuminated with light having a known spectrum composition and the intensities of three primary colours are measured opto-electrically in the reflected or transmitted light as colour components, which represent the spatial co-ordinates of the colour locations (point of space) in a colour space, and wherein colour recognition spaces are delimited for each colour to be recognised in the colour space and the measured colour components are verified regarding their correspondence to the colour recognition spaces, wherein, prior to the colour determination for each colour or spatial colour range which is to be recognised, the colour components of at least one characteristic sample dot in the colour or colour range in question are determined and noted, an identification symbol is co-ordinated with each trio of colour components, and the coloured surface is scanned opto-electrically for actual colour determination, the colour components thereby obtained are compared to the colour components noted, and in case of correspondence, the co-ordinated identification symbols are emitted.

The invention also consists in a method for the recognition of colours in which a coloured surface is illuminated with light having a known spectrum composition and the intensities of three primary colours are measured opto-electrically in the reflected or transmitted light as colour components, which represent the spatial co-ordinates of the colour locations in a colour space, and in which colour recognition spaces are delimited for each colour to be recognised in the colour space and the measured colour components are verified regarding their correspondence to the colour recognition spaces, wherein, prior to the colour determination for each colour or colour range which is to be recognised, the colour components of at least one characteristic sample dot in the colour or colour range in question are determined and noted, an identification symbol is co-ordinated with each colour component triplet of a sample dot, and wherein, for forming colour recognition spaces around the sample colour locations prior to the actual colour determination, each colour locus or colour component triplet which is to be covered is associated with the identification symbol of the sample colour locus lying spatially closest said colour locus in the colour space, the coloured surface is scanned opto-electrically during actual colour determination to obtain colour components, and the identification symbols co-ordinated with the colour components or colour locations in question are emitted.

The invention also consists in a method for the recognition of colours in which a coloured surface is illuminated with light having a known spectrum composition and the intensities of three primary colours in the reflected or transmitted light are measured opto-electrically as colour components, which represent the spatial co-ordinates of the colour locations in a colour space, and in which colour recognition spaces are delimited in the colour space for each colour which is to be recognised and the colour components measured are verified regarding their correspondence to the colour recognition spaces, wherein, prior to the colour determination, the colour components of at least one characteristic sample colour locus within the colour or spatial colour range in question are determined and noted for each colour or each colour region which is to be recognised, an identification symbol is co-ordinated with each colour component triplet of a sample colour and wherein, for the purpose of forming colour recognition spaces around the sample colour locations prior to the actual colour determination, the colour locations to be specified by identification symbols, which surround the sample colour locations in shell form, are called shell by shell as the distance increases from the sample colour locations in question, the colour locations called are checked in respect of being marked by identification symbols, the identification symbol of a sample colour locus is allocated to a colour locus called from a specimen colour locus, if the colour locus in question has not as yet been allocated an identification symbol, the colour surface is scanned opto-electrically during actual colour determination for obtaining colour components, and the identification symbols previously allocated to the corresponding colour components or colour locations are issued.

The invention also consists in a method for the recognition of colours in which a coloured surface is illuminated with light having a known spectrum composition and the intensities of three primary colours in the reflected or transmitted light are measured opto-electrically as colour components which represent the spatial co-ordinates of the colour locations within a colour space, and in which colour recognition spaces are delimited in the colour space for each colour which is to be recognised, and the colour components measured are verified regarding their correspondence to the colour recognition spaces, wherein, prior to colour determination, for each colour or spatial colour range which is to be recognised, the colour locus of at least one characteristic sample dot in the colour or colour range in question is determined and noted in the form of colour components, an identification symbol is allocated to each sample colour locus of a sample dot, and wherein, for forming colour recognition spaces around the sample colour locations, the colour locations which surround the sample colour locations in the form of shells are called shell by shell at increasing distance from the sample colour locations in question and are checked regarding being tagged with identification symbols, the identification symbol of a sample colour locus is allocated to a colour locus called from said sample colour locus, if the colour locus in question is not as yet tagged with an identification symbol, the forming of the shells around the sample colour locations is stopped, the colour locations which are not yet tagged have thereupon allotted to them in each instance the identification symbol of the sample colour locus which is closest spatially within the colour space, and wherein, during actual colour determination, the coloured surface is scanned opto-electrically to obtain colour components and the identificaton symbols previously allocated to the corresponding colour components or colour locations are issued.

Furthermore the invention consists in a circuit arrangement for the recognition of colours and including a source of light of known spectrum composition for illumination of the coloured surface which is to be examined, and three opto-electronic transducers for detection of the reflected or transmitted intensities of three primary colours as colour components, wherein a colour recognition memory is connected via "A/D" transducers to the opto-electronic transducers and intended for reception of identification symbols, said memory being addressable by means of digitalised colour components, and further comprising an input stage for allocation of identification symbols, a sample memory connected to the input stage and the "A/D" transducers for storage of a sample list compiled from the colour components of the sample dots and the co-ordinated identification symbols, an address control system connected to the colour recognition memory and to the sample memory and intended for calling colour components and for selection of the addresses of the sample memory and of the colour recognition memory, and a calculator circuit connected to the sample memory, the address control system and the colour recognition memory and intended to ascertain the identification symbols from the colour components called and from the sample list.

The invention also consists in a circuit arrangement for the recognition of colours and including a source of light of known spectrum composition for illumination of the coloured surface which is to be examined, and comprising three opto-electronic transducers for determination of the reflected or transmitted intensities of three primary colours as colour components, wherein a colour recognition memory is connected via an "A/D" transducer to the opto-electronic transducers and intended for reception of identification symbols, which is addressable by means of digitalised colour components and further comprising an input stage for allocation of identification symbols, a sample memory connected to the input stage and to the "A/D" transducers and intended for storing a sample list compiled from the colour components of the sample dots and the co-ordinated identification symbols, a shell memory for storing the shell co-ordinates in the form of shell list, an address control system connected to the sample memory and the shell memory for calling addresses of said memories, a calculator circuit connected to the sample memory, the shell memory and the colour recognition memory for calculating and calling the addresses of storage locations of the colour recognition memory which are to be tagged by identification symbols and for determining the corresponding identification symbols, and a switching stage for checking the storage locations called in respect of being tagged with identification symbols.

The invention also consists in a circuit arrangement for the recognition of colour and including a source of light of known spectrum composition for illumination of the coloured surface which is to be examined, and comprising three opto-electronic transducers for determination of the reflected or transmitted intensities of three primary colours as colour components, wherein a colour recognition memory is connected via "A/D" transducers to the optoelectronic transducers and intended for reception of identification symbols, which is addressable by means of digitalised colour components and further comprising an input stage for allocation of identification symbols, a sample memory connected to the input stage and the "A/D" transducers for storing a sample list compiled from the colour components of the sample dots and the co-ordinated identification symbols, a shell memory for storing the shell co-ordinates in the form of a shell list, an address control system connected to the sample memory, the shell memory the colour recognition memory and intended for calling the sample list and the shell list, a calculator circuit connected to the sample memory, the address control system, the partial shell memory and the colour recognition memory and intended for calculating and calling the addresses of storage locations which are to be tagged with identification symbols of the colour recognition memory and for determining the corresponding identification symbols, and a switching stage for checking the storage locations called regarding being tagged with identification symbols.

In order that the invention may be more clearly understood, reference will now be made to the accompanying drawings which show certain embodiment thereof by way of example and in which:-

Figure 1 shows a first embodiment of circuit arrangement circuit for colour recognition,
Figure 2 shows a flow chart regarding the operation of the circuit layout;
Figure 3 shows a chrominance-luminance colour space subdivided into spatial elements
Figure 4 shows a graphic illustration appertaining to the determination of the spatial distances of space elements,
Figure 5 shows a cross-section through the chrominance-luminance colour space;
Figure 6 shows a second embodiment of circuit arrangement for colour recognition,
Figure 7 shows a flow chart for determination of the partial sphere co-ordinates,
Figure 8a - 8d show graphic illustrations concerning the forming of partial spheres,
Figure 9 shows a flow chart regarding the operation of the circuit arrangement,
Figure 10 shows a third embodiment of circuit arrangement for colour recognition,
Figure 11 shows a flow chart regarding the operation of the circuit arrangement,
Figure 12 shows another flow chart regarding the operation of the circuit arrangement,
Figure 13 shows a modification of the circuit arrangements,
Figure 14 shows a cross-section through the saturation/hue/brightness colour space,

Figure 15 shows an example of application of the circuit arrangements in a colour scanner for textile, decorative or packaging printing, and

Figure 16 shows an example of application of the circuit arrangements in a colour scanner for multicolour printing.

Referring now to the drawings, Figure 1 shows a first embodiment of circuit arrangement for colour recognition or colour separation, and Figure 2 shows a flow chart in explanation of its operation.

The coloured original which is to be analysed may be a pictorial or pattern model for multicolour printing or for textile, decorative and packaging printing, but also a draft pattern for securing control data for textile processing machinery. The terms "coloured original" should also be taken as referring to a coloured print medium and generally any coloured area or surface.

The coloured original is to consist of adjacent areally applied colours and of flowing colours. The areal colours display colour deviations, e.g. because of colour tolerances or uneven colour application. The problem arises during colour recognition, of separating the individual areal colours from each other, and of combining the colour deviations into a colour within an area. In the flowing colours, i.e. in the colours displaying gradual changes in saturation and/or brightness, the colour fluctuations are the result of deliberate design. During colour recognition, the problem then arises of separating the individual colour variations (extensions) from each other, or else - if appropriate - of combining several colour deviations into one colour.

The coloured original 1, which is installed on a support 2, is illuminated by two sources 3 and 4 of light known spectrum composition, and the reflected or transmitted scanning light passes via objective lenses 5 and 6 and via a shutter 7 into a scanning unit 8. In the scanning unit 8, the scanning light is split by means of two dichroic colour separators 9 and 10 into three partial beams which impinges on three opto-electronic transducers 14, 15 and 16 through corrective colour filters 11, 12 and 13. The transducers 14, 15 and 16 convert the light beam components received into the primary colour measurements signals R, G and B as a function of the intensities of the primary colour components in the colours scanned, which signals represent the spatial co-ordinates of the corresponding colour locations in the Cartesian R, G, B colour space.

The colour mensuration signals R, G and B are converted into logarithms in a logarithmation stage 17 and/or modified in accordance with a graduating function. In a transducer stage 18, the colour mensuration signals R, G and B are changed into matrix form into the chrominance signals x and y and into the luminance signal z in accordance with the relationship:

$$x = a_{11}R + a_{12}G + a_{13}B$$
$$y = a_{21}R + a_{22}G + a_{23}B$$
$$z = a_{31}R + a_{32}G + a_{33}B$$

Matrix production corresponds to a conversion of the R, G, B colour space into the chrominance-luminance colour space, the chrominance signals x and y representing the colour co-ordinates of the colour locations in the chrominance plane, and the luminance signals z representing the third co-ordinate (grey axis). Conversions of this nature are familiar in television technology.

The chrominance signals x and y and the luminance signal z are converted in the "A/D" transducers 19, 20, 21 into digital signals having a word size of 5 bits in each case, which are delivered via output lines 22, 23, 24. The conversion into digital form may also be performed with differing resolution.

For elucidation, Figure 3 shows how the entire chrominance-luminance colour space 25 is subdivided into a plurality of colour space elements 26 or colour locations amounting to 32 × 32 × 32 in the embodiment, of which a few only are shown to simplify matters. The colour of a colour space element 26 or its position in the chrominance-luminance colour space 25, is defined by a spatial vector $\vec{F}$ or by the corresponding colour space co-ordinates x, y and z.

Freely selectible identification symbols, e.g. colour numbers (C-Nos.) 1, 2, 3, etc., are allocated to the individual colours or colour space elements 26. Each spatial colour range in the coloured original 1 which is to be recognised during colour separation as appertaining to an individual colour, is delimited by a colour recognition space 27 in the chrominance-luminance colour space 25. The colour space elements 26 which correspond to one colour recognition space are tagged with the same colour number. Figure 3 shows a first colour recognition space 271 having the colour number "1" as well as parts of a second colour recognition space 272 having the colour number "2" and of a third colour recognition space 273 having the colour number "3". The number of colour recognition spaces 27 depends on the number of colours which are to be separated. As a rule, the individual colour recognition spaces are directly adjacent to each other so that no undefined conditions arise.

The circuit arrangement for colour recognition according to Figure 1 comprises a colour recognition memory 28 having an address input terminal 29, a data input terminal 30 and a data output terminal 31. In the embodiment, the colour recognition memory 28 has a capacity of 32 × 32 × 32 times 4 bits. Each storage locus has allocated to it a colour space element 26 of the chrominance-luminance colour space 25. Each storage locus may be addressed by the colour co-ordinates x, y and z of the corresponding colour space element 26. The colour numbers "1" to "16" which are allocated to the colour space elements 26 are stored at the storage points.

The output conductors 22, 23 and 24 of the A/D transducers 19, 20 and 21 are combined into a multiple address connector or bus 32, which is connected to the address input terminal 29 of the colour recognition memory 28 via a selector switch 33. The digital signals x, y and z of 5 bits each are in each case combined into a 15-bit address and are transmitted to the colour recognition memory 28 via the address bus 32 for selection of the stored addresses.

For subsequent recognition of the colours of the original, the required colour numbers are allocated to the appropriate colour co-ordinate combinations x, y and z, and are stored under corresponding addresses of the colour recognition memory 28.

During actual colour recognition, the scanning unit 8 then scans the coloured original 1 by points and lines by means of a relative displacement between the scanning unit 8 and the model carrier 2. The colour co-ordinates (addresses) concomitantly obtained place a call via the address bus 32 and the selector switch 33 to the corresponding colour numbers in the colour recognition memory 28 which are read out of the colour recognition memory 28 via the data output terminal 31 and processed subsequently. The selector switch 33 is then placed in the switching position shown chain-dotted.

If for example, a particular spatial colour range is to be recognised as an individual colour having the colour number "N", the colour number "N" is allocated in the colour recognition memory 28 to all the colour co-ordinate combinations (address combinations) x, y and z situated in this spatial colour range. If these address combinations appear again during subsequent scanning of the original, the corresponding colour having the the colour number "N" is recognised.

If the totality of spatial colour ranges of the colours available in the coloured original 1 is substantially smaller than the the retically possible R, G, B colour space or chrominance-luminance colour space, an appropriate address re-calculation may be performed in advantageous manner for complete exploitation of the colour recognition memory 28.

In accordance with the invention, determining the colour numbers and loading the colour recognition memory 28 are performed with respect to the coloured original 1 which is to be analysed, by means of the scanning unit 8 and of an allocating circuit 34.

The allocating circuit 34 comprises an input stage 35, a sample memory 36, an addess control system 37 and a calculator circuit 38. The input stage 35 has a first operating section 35′ comprising a 10-key keyboard for presetting colour numbers and a second operating numbers and a second operating section 35″ comprising a number of operating keys.

The operation of the allocating circuit 34 is described in particular in the following.

To obtain the great number of colour numbers required to take up the capacity of the colour recognition memory 28 totally or almost totally, a substantially smaller number of colour specimens is initially taken from the coloured original 1 and colour numbers are allocated to these colour specimens. This sets up a supporting framework from which the colour numbers required to establish the structure of the colour recognition spaces may be ascertained automatically and stored in the colour recognition memory 28.

Sampling

As an initial step, at least one colour specimen is picked from the coloured original 1 for each colour which is to be recognised, and a colour number is allocated to each colour specimen. To this end, the scanning unit 8 is driven to characteristic sample dots P_n in the individual colours, and the colour mensuration signals R, G and B are measured. The sample colour co-ordinates x_{pn}, y_{pn} and z_{pn} obtained in this manner are fed via the address bus 32 to the data input terminal 39′ of the sample memory 36. At the same time, the operator establishes a sample list by allocating a colour number "N" (4 bits) to each triplet of sample colour co-ordinates x_{pn}, y_{pn} and z_{pn} (15 bits) by means of the input stage 35, which (triplet-s) are fed via the data bus 40 to the data input terminal 39″ of the sample memory 36.

Each line of the sample list is stored in the sample memory 36 in the form of 19-bit stored words under consecutive addresses which are called up by the address control system 37 via the address input terminal 41. To this end, the operative actuates a "sample" operating key 42 in the operating section 35″ of the input stage 35, so that the addresses in the address control system 37 are increased by one in each case by an appropriate order on a conductor 43.

The number of colour samples depends substantially on the nature of the colours which are to be recognised, on the coloured original and on the precision required for the colour separation.

An example for establishing an allocation (or co-ordination) list is given in the following.

A colour "blue" which is to be recognised in an area 44 of the coloured original 1 is assumed to have a homogenous saturation and brightness. In this case, it is sufficient to extract no more than one colour specimen at a sample dot P_1, and to allocate the colour number "1" for example, to the sample colour co-ordinates x_{p1}, y_{p1} and z_{p1} of the colour for recognition "blue".

A second colour which is to be recognised in an area 45 is assumed to be shaded, e.g. to include the spatial colour range "light red" and "dark red" which are to be combined into one colour "red" for recognition. In this case, the sample dot P_2 in the colour range "light red" is measured first, and the specimen colour co-ordinates x_{p2}, y_{p2} and z_{p2} have allocated to them the colour number "2" of the recognition colour "red". A colour sample is then extracted at the sample dot P_3 in the spatial colour range "dark red" and the colour number "2" of the recognition colour "red" is equally allocated to the specimen colour co-ordinates z_{p3}, y_{p3} and x_{p3}.

A third colour in another area 46 of the coloured original 1 is equally assumed to be shaded, e.g. to include

the spatial colour ranges "pale yellow", "medium yellow" and "dark yellow", which are to be separated from each other. In this case, at least one colour specimen is extracted in each spatial colour range (sample dots P_4, P_5 and P_6), and the colour number "3" of the recognition colour "pale yellow" is allocated to the corresponding sample colour co-ordinates x_{p4}, y_{p4} and z_{p4}, the colour number "4" of the recognition colour "medium yellow" is allocated to the sample colour co-ordinates x_{p5}, y_{p5} and z_{p5}, and finally, the colour number "5" of the recognition colour "dark yellow" is allocated to the sample colour co-ordinates x_{p6}, y_{p6} and z_{p6}.

With the extraction of a colour sample from an nth sample dot and the allocation of the colour number "N", the following sample list is established and stored.

Specimen Point	Address	Storage Value C-No.	Storage Value Specimen Colour co-ordinates
P_1	1	1	$x_{p1};y_{p1};z_{p1}$
P_2	2	2	$x_{p2};y_{p2};z_{p2}$
P_3	3	2	$x_{p3};y_{p3};z_{p3}$
P_4	4	3	$x_{p4};y_{p4};z_{p4}$
P_5	5	4	$x_{p5};y_{p5};z_{p5}$
P_6	6	5	$x_{p6};y_{p6};z_{p6}$
.	.	.	.
.	.	.	.
.	.	.	.
.	.	.	.
P_n	n	N	$x_{pn};y_{pn};z_{pn}$

The coloured original 1 may also be depicted on a colour monitor and the colour specimens may be determined by means of a cursor and of an appropriate measuring circuit. To this end, the coloured original 1 is scanned with a television camera. In the case in which the coloured original 1 which is to be analysed had already been scanned beforehand in a colour scanner and the digital colour data have been stored in an image memory, the colour data are loaded into an image repeater memory and read out cyclically for reproduction on the colour monitor.

Determination of the colour numbers

Following the specified first step of sample extraction, colour numbers are already allocated to the colour space elements which correspond to a colour specimen (specimen colour space elements). Each additional colour space element $(x_i;y_i;z_i)$ is subsequently tagged with the colour number of the spatially closest specmen colour space element (x_{pn},y_{pn},z_{pn}). To determine the colour numbers, it is necessary to calculate the distance within the colour space between a colour space element which is to be tagged and the individual specimen colour space elements, and to determine the shortest distance.

For elucidation, Figure 4 again shows the chrominance-luminance colour space 25 with a colour space element 26 which is to be tagged, and which is defined by the spatial vector $\vec{F}_i$ or by the colour co-ordinate triplet x_i,y_i and z_i and comprising two specimen colour space elements 26' and 26" which are defined by the spatial vectors $\vec{F}_{p1}$ and $\vec{F}_{p2}$ or by the colour co-ordinates (x_{p1},y_{p1},z_1) and (x_{p2},y_{p2},z_{p2}). The specimen colour space elements 26' and 26" have the distances d_1 and d_2 from the colour space element 26 which is to be tagged. Let us assume that the colour number "1" is allocated to the specimen colour space element 26', and that the colour number "2" is allocated to the specimen colour space element 26".

The distance d_n of a colour space element (x_i,y_i,z_i) from a specimen colour space element (x_{pn},y_{pn},z_{pn}) is determined by means of the vectorial distance equtiion:

$$d_n = \sqrt{(x_i - x_{pn})^2 + (y_i - y_{pn})^2 + (z_i - z_{pn})^2}$$

In the example selected, the distances d_1 and d_2 are calculated accordingly and compared to each other.

Since $d_2<d_1$, the colour space element 26 is tagged with the colour number "2". If the same distance is determined between the colour space element called and several specimem colour space elements, a majority decision may be implemented, by tagging the colour space element called with the colour number occurring most frequently in the equidistant colour specimens.

To determine the colour number of an actual colour space element, it would also be possible to scan the surrounding colour space elements at increasing distance and to check these regarding being tagged with a colour number. The actual colour space element then receives the colour number which is the first to be encountered upon scanning the surrounding space.

The determination of the colour numbers and the loading of the colour recognition memory are performed in the following manner in the circuit arrangement according to Figure 1.

The operative actuates an operating key 47 for "memory charging" in the operating section 35" of the input stage 35, whereby a control order is transmitted via a conductor 48 to the address control system 37.

The address control system 37 calls up the colour co-ordinates x_i,y_i and z_i of a colour space element (storage locus) which is to be tagged, and transmits these colour co-ordinates via data bus 49 and a data input terminal 50 to the calculator circuit 38.

Complementarily, the address control system 37 also calls via the address input terminal 41 on the first address of the sample memory 36 under which are stored the specimen colour co-ordinates x_{p1},y_{p1} and z_{p1} as well as the corresponding colour number of the first sample (first line of the sample list), and transfer these values to the calculator circuit 38 as well, via the data input terminals 53 and 54.

The calculator circuit 38 then determines the distance d_1 in accordance with the equation specified above, and stores the value calculated in an internal register.

The address control system 37 then calls up the second address of the sample memory 36 and transcribes the second line of the sample list containing the data regarding the second colour specimen into the calculator circuit 38, which then determines the distance d_2 and stores the latter. This operation is concluded with the calculation of the distance d_n from the n-th colour specimen, and the minimum distance d_{min} is also determined at the same time.

The colour co-ordinates x_i,y_i and z_i called up by the address control system 37 simultaneously call up the corresponding addresses of the colour recognition memory 28 via an address bus 55 and the selector switch 33 which is situated in the switching position illustrated. The colour number which is allocated to the minimum distance d_{min} determined is transcribed from the calculator circuit 38 via a data bus 56, another selector switch 57 and via the data input terminal 30 into the colour recognition memory 28, and is stored under the address selected.

Subsequently, the address control system 37 calls up the colour-ordinates (addresses) of another colour space element (storage locus) which is to be tagged, and the determination of the colour numbers and their transcription into the colour recognition memory 28 are performed as hereinabove described.

The address control system 37 may call up the addresses of the colour recognition memory 28 in an optional sequence or limit these to a particular range, if no more than one or a few colour recognition spaces are to be delimited.

The delimitation of one or more colour recognition spaces is adequate if the coloured signal 1 scanned is a control "mask" for example and if no more than a few mask signals need be obtained, or if the output signals of the colour recognition memory 28 are to be applied to control a selective colour correction. In all other cases of application, a total occupation of the colour recognition memory commonly proves to be advantageous since undefined colour conditions then cannot arise and since a high reliability of recognition is secured during colour separation. In this case, it is appropriate to call up the addresses of the colour recognition memory 28 line-by-line.

Another advantageous method of operation of the circuit system is the following.

If, for example, one area of the coloured original 1 is to be recognised whilst taking a shaded colour as an individual colour having the colour number "N", the possibility exists complementarily in the circuit system of guiding the scanning unit 8 in closely spaced displacements over the area in question, to grasp as many colour co-ordinate triplets x, y and z of this area as possible. For this method of operation, the selectors 33 and 37 are situated in the switching positions shown chain-dotted, and the colour co-ordinates perform a direct selection of the corresponding addresses of the colour recognition memory 28. Simultaneously with the displacement of the scanning unit 8, the operative keys in the colour number "N" by means of the 10-digit keyboard of the input stage 35, which is then stored under all the addresses called in the colour recognition memory 28 via a data bus 58, the switch 57 and the data input terminal 30. The totality of the storage locations tagged with the colour number "N" forms the colour recognition space for the individual colour which is to be recognised.

The colour recognition memory 28 may evidently also be occupied to capacity by extracting no more than a sufficiently large number of colour specimens from the coloured original.

In essence, the process described has the advantage that the size, shape and directional setting of the colour recognition spaces within the colour space may be influenced by selection of the colour specimens. The colour recognition spaces may thereby be adapted in optimum manner to the spatial colour ranges which are to be separated, thereby securing a high reliability of recognition. The colour recognition spaces are consequently not inflexibly specified but may be adapted individually by means of the sampling operation to the coloured original which is to be scanned at that time. Consequently, only as many colour

recognition spaces as there are colours to be separated in the coloured originals, are established in each case.

For illustration of the sequence described in the foregoing, Figure 5 shows a chrominance plane as a secting plane (z = constant) through chrominance-luminance colour space. During the sampling operation, the colour numbers "1", "2" and "3" were allocated to the specimen colour space elements 261, 262 and 263. After determining the colour numbers and loading the colour recognition memory 28 to capacity, all the colour space elements of this chrominance plane are tagged with colour numbers. Three colour recognition spaces delimited from each other by the lines 59 are formed around the specimen colour space elements 261, 262 and 263.

Figure 6 shows a second embodiment for a circuit arrangement for colour recognition, which differs from Figure 1 by a modified allocating circuit 34'.

The allocating circuit 34' again comprises the input stage 35, the sample memory 36, the address control system 37, a modified calculator circuit 38' and complementarily a partial sphere memory 62 and a gate circuit 63. The operation of the allocating circuit 34' is to be described in particular in the following.

The sampling operation corresponds to the procedure depicted in Figure 1, so that the charging of the colour recognition memory may be dealt with immediately.

Charging the colour recognition memory

Following the sample operation, colour numbers have already been allocated to the colour space elements which correspond to a colour specimen (specimen colour space elements). Starting from these specimen colour space elements, the colour recognition spaces are then built up from the individual colour space elements, the corresponding colour numbers are determined and finally, the colour numbers determined are stored in the colour recognition memory 28.

The extension of the colour recognition spaces within the chrominance-luminance colour space is performed in accordance with the invention in spherical or cubical form, by plotting partial spheres or partial cubes at increasing radii around the specimen colour space elements. The colour space elements co-opted to form the partial spheres or partial cubes are checked at the same time to ascertain whether they had already been tagged with a colour number or not, during the sampling operation. In case a colour number has not as yet been allocated to a checked colour space element, this element receives the colour number of the corresponding central specimen colour space element. If the colour space element checked has already been tagged with a colour number, the extension of the colour recognition space is interrupted at this point. Partial spheres were plotted in the example of application.

These operations are to be described exhaustively.

Structure of the partial spheres

The individual partial spheres around the colour specimens are approximated by appropriate colour space elements. The spatial vectors $\vec{F}_{sm}$ of the colour space elements participating in forming the partial spheres, or their partial sphere co-ordinates x_{sm}, y_{sm} and z_{sm} with respect to an auxiliary co-ordinate system having its origin in the colour specimen in question, were already determined prior to colour recognition and stored in tabular form, partial sphere by partial sphere, in the partial sphere memory 62.

The partial sphere co-ordinates x_{sm}, y_{sm} and z_{sm} fulfil the general spherical equation:

$$r_m = \sqrt{x_{sm}^2 + y_{sm}^2 + z_{sm}^2}$$

with the radius $r_1 = 1$ for the first partial sphere, the radius $r_2 = \sqrt{2}$ for the second partial sphere, the radius $r_3 = \sqrt{3}$ for the third partial sphere, and in general with the radius $r_m = \sqrt{m}$ for the m-th partial sphere.

The quantity of all integral value triplets complying in each case with the spherical equation for a predetermined radius r_m, i.e. the sum of whose squares is equal to m^2, produces the partial sphere co-ordinates x_{sm}, y_{sm} and z_{sm} of the colour space elements appertaining to the m-th partial sphere. Based on at least one representative and ordered partial sphere co-ordinate triplet for the m-th partial sphere, all the other partial sphere co-ordinates x_{sm}, y_{sm} and z_{sm} are obtained by permutation and sign reversal.

The determination of the partial sphere co-ordinates by means of digital counters, which is depicted in Figure 7 in respect of a flow chart, appears in the following guise, for example:

Zero partial sphere ($r_o = 0$)

This corresponds in each instance to a specimen colour space element having the specimen colour co-ordinates x_{pn}, y_{pn} and z_{pn}. The partial sphere co-ordinates are equal to zero.

First partial sphere ($r_1 = 1$)

Representative partial sphere co-ordinate triplet: (0,0,1)

Partial sphere co-ordinates: (0,0,1); (0,1,0); (1,0,0); (−1,0,0); (0,−1,0); (0,0,−1).

Second partial sphere ($r_2 = \sqrt{2}$)

Representative partial sphere co-ordinate triplet: (0,1,1).

Partial sphere co-ordinates: (0,1,1); (1,0,1); (1,1,0); (0,1,−1) etc.

Third partial sphere ($r_3 = \sqrt{3}$)

Representative partial sphere co-ordinate triplet : (1,1,1).

This again yields the corresponding partial sphere co-ordinates.

Figure 8 shows the forming of the first three partial spheres from the colour space elements 26 in a spatial form of illustration.

A specimen colour space element 26' is illustrated in a), the colour space elements 26 of the first partial sphere are illustrated around this specimen colour space element 26' in b), the colour space elements 26 of the second partial sphere are complementarily illustrated in c), and the additional colour space elements 26 of the third partial sphere are illustrated in d). The representative colour space element 26" and its partial sphere co-ordinates are simultaneously indicated in each instance.

Determination of the colour co-ordinates (addresses x_i; y_i; z_i)

The colour co-ordinates x_i, y_i and z_i of the colour space elements 26 participating in forming partial spheres around a colour specimen in the chrominance-luminance colour space or the corresponding addresses of the colour recognition memory 28 emerge from the partial sphere co-ordinates x_{sm}, y_{sm}, z_{sm} and the specimen colour co-ordinates x_{pn}, y_{pn} and z_{pn} in accordance with the equations:

$$\begin{aligned} x_i &= x_{pn} + x_{sm} \\ y_i &= y_{pn} + y_{sm} \\ z_i &= z_{pn} + z_{sm} \end{aligned} \qquad (3)$$

The determination of the individual colour co-ordinate triplets is performed in a sequence such that the first partial sphere is first placed around each colour specimen, that the second partial sphere is placed thereafter around each colour specimen, and so on consecutively. The flow chart of Figure 9 elucidates this sequence.

The tagging of the storage locations of the colour recognition memory 28 with colour numbers is initiated by actuation of a "memory charging" operating key 47, whereby a corresponding control instruction is transmitted via a line 48 to the address control system 37 and the calculator circuit 38'. All the storage locations of the colour recognition memory 28 are thereby initially tagged with the colour numbers "0".

For scanning (or interrogation) of the stored sample list and partial sphere list, the address control system 37 is connected to the sample memory 36 and the partial sphere memory 62 via the address buses 41 and 64.

The partial sphere co-ordinates x_{sm}, y_{sm} and z_{sm} are transcribed via the data bus 65, the specimen colour co-ordinates x_{pn}, y_{pn} and z_{pn} are transcribed via the data bus 52, and the corresponding colour numbers are transcribed via the data bus 51 into the calculator circuit 38'. The colour co-ordinates x_i, y_i and z_i which call up the corresponding addresses of the colour recognition memory 28 via the address bus 55, the selector 33 and the address input terminal 29, are determined in the calculator circuit 38' from the transcribed co-ordinates, in accordance with the specified equations (3).

The partial sphere list of the zero partial sphere (x_s=y_s=z_s=0) and the entire sample list are initially fed line-by-line into the calculator circuit 38'. In this case, the calculated colour co-ordinates x_i, y_i and z_i are in each instance identical to the specimen colour co-ordinates x_{pn}, y_{pn} and z_{pn} of the individual colour specimens, and the corresponding colour numbers of the colour specimens are stored under the addresses called up in the colour recognition memory 28. The colour numbers are transmitted from the calculator circuit 38' to the colour recognition memory 28 via the data bus 56, the gate circuit 63, the selector 57 and the data input terminal 30.

In a next stage, the partial sphere list for the first partial sphere is fed into the calculator circuit 38' and the sample list is again gone through line-by-line, the colour co-ordinates x_i, y_i and z_i of the first partial sphere around each colour specimen being calculated consecutively. These colour co-ordinates again address the colour recognition memory 28. Each storage locus addressed is simultaneously checked regarding its possibly already performed tagging with a colour number. To this end, the gate circuit 63 is connected via a data line 66 to the data output terminal 31 of the colour recognition memory 28. If tagging is present, the gate circuit 63 is blocked so that no colour number may be entered into the colour recognition memory 28 via the data bus 56. If there is no tagging however, the gate circuit 63 is unblocked, and the colour number of the colour specimen around which a partial sphere is just being formed is stored under the address which is being called at the time.

Ever more partial spheres are thus placed around the individual colour specimens until one or more colour recognition spaces or the entire colour space, are tagged with colour members.

The charging of the memory and the extension of the individual colour recognition spaces around the colour specimens may be interrupted at will or in accordance with particular criteria.

For example, the establishment of a particular spherical radius or the tangency of spheres of adjacent colour specimens, may be co-opted as criteria. The sphere radius at which the expansion of a colour recognition space is to be terminated could be made a function of the number of colour specimens which are to be determined. Said termination could also be determined by the frequency with which colour space elements already tagged with colour numbers are encountered whilst forming partial spheres. Figure 5 again depicts the result of memory charging.

The colour recognition memory 28 may obviously also be charged by extracting no more than an adequately large number of colour specimens from the coloured original as depicted in Figure 1, or by guiding the scanning unit 8 over the area in question and by feeding in the colour number "N" by means of the 10-digit keyboard.

The method described equally has the advantage that the size, form and directional setting of the colour recognition spaces in the colour space may be influenced by selection of the colour specimens in the original. The colour recognition spaces may thereby be adapted in optimum manner to the spatial colour ranges areas which are to be separated, thereby equally securing high reliability of recognition. The colour recognition spaces are consequently not specified inflexibly, but may be adapted individually by specimen extraction to the coloured original which is to be scanned at the time. For this reason no more colour recognition spaces are set up than there are colours to be separated from each other in the original.

Figure 10 shows a third embodiment of a circuit arrangement for colour recognition, in which the memory charging methods depicted in Figures 1 and 6 are applied in combination.

The allocating circuit 34" accordingly comprises functional units of the allocating circuit 34 of Figure 1 and of the allocating circuit 34' of Figure 6.

Consequently, the allocating circuit 34" again comprises the input stage 35, the sample memory 36, the partial sphere memory 62, the address control system 37, a modified calculator circuit 38" and the gate circuit 63.

The method of operation of this embodiment is as follows:

The sample extraction again evolves as depicted in Figure 1, so that the charging of the colour recognition memory 28 may be initiated immediately. Determination of the colour numbers and charging of the colour recognition memory

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This operation occurs in two separate stages.

In the first stage (preloading) the colour recognition spaces are expanded around the individual specimen colour space elements in the form of partial spheres or cubes as in the method depicted in Figure 6. To this end, the corresponding colour space elements (colour locations) which surround the specimens in the manner of shells, are called up partial sphere by partial sphere at increasing distance and checked regarding whether they had already been tagged with a colour number or not, during sample extraction.

In the case in which no colour number has as yet been allocated to a colour space element thus checked, the latter receives the colour number of the corresponding central specimen colour space element. The forming of the partial spheres has already been depicted expressly in Figures 6, 7, 8 and 9.

The forming of partial spheres is interrupted for initiation of the second stage.

In the second stage, the colour numbers of the specimen colour locations which are spatially closest within the colour space are allocated to the as yet untagged colour space elements in accordance with the process depicted in Figure 1.

The charging of the colour recognition memory 28 is then completed.

A. *Preloading the colour recognition memory*

In a subsequent step, the partial sphere list for the first partial sphere (or spherical shell) is fed into the calculator circuit 38" and the sample list is again worked through line-by-line, the colour co-ordinates x_i, y_i and z_i of the first spherical shell around each colour specimen being calculated consecutively. The colour co-ordinates again address the colour recognition memory 28. At the same time, each storage locus addressed is checked regarding its possibly already performed tagging with a colour number.

If tagging has been performed the gate circuit 63 is blocked, so that no colour number may be written in the colour recognition memory 28 via the data bus 56. If there is no tagging on the contrary, the gate circuit 63 is unblocked and the colour number of the colour specimen around which a spherical shell is just being formed is stored under the address being called at the time.

Ever more spherical shells are placed around the individual colour specimen in this manner, until the forming of the spherical shells is stopped. The criteria specified in Figure 6 may again be co-opted for interruption of the forming of the spherical shells.

After stopping the forming of spherical shells, the individual colour recognition spaces have been expanded within the colour space. Colour numbers have not as yet been allocated to all the colour space elements however.

B. *Residual charging of the colour recognition memory*

During the residual charging operation, the colour numbers of the specimen colour space elements (n) which are spatially closest in each case and have the colour components x_{pn}, y_{pn} and z_{pn} are allocated to the colour space elements which have the colour components x_i, y_i and z_i and have not as yet been tagged by the end of the forming of the partial spheres or shells.

To determine the colour numbers, it is again necessary to calculate the distance within the colour space between a colour space element which is to be tagged and the individual specimen colour space elements, and to determine the smallest distance. This process, which has already been depicted in particular in Figures 1, 2 and 4, occurs in the following manner:

Reaching a predetermined shell radius is exploited in the embodiment as a criterion for stopping the forming of shells or partial spheres. This shell radius is entered in the sample list stored in the sample memory 36. When this shell radius is encountered whilst working off the sample list, the calculator circuit 38" feed a "stop" order to this address control system 37 via a line 67.

The address control system 37 calls consecutively and line-by-line on all colour co-ordinates x_i, y_i and z_i or addresses of the colour recognition memory 28 via the address bus 65, the selector 33 and the address input terminal 29. At the same time, the storage locations called are checked regarding an already performed tagging with colour numbers, by reading the corresponding colour numbers out of the colour recognition memory 28 into the gate circuit 63 via the data bus 66. If a storage locus occupied by the colour number "0" is encountered at the same time, the gate circuit 63 generates an instruction "unoccupied" which is transmitted to the address control system 37 via a conductor 68.

The address control system 37 interrupts the calling of the addresses and records the corresponding address of the as yet unoccupied storage locus.

The corresponding colour components (x_i, y_i, z_i) are transmitted by the address control system 37 to the calculator circuit 38" via another data bus 69. The address control system 37 activates the calculator circuit 38" by means of an order "distance calculation" on a line 70 and moreover calls via the address bus 41 on the first address of the sample memory 36, under which the specimen colour components x_{p1}; y_{p1}; z_{p1} as well as the corresponding colour number of the first colour specimen (first line of the sample list) are stored. The called values of the sample list are transcribed into the calculator circuit 38" via the data buses 51 and 52.

The calculator circuit 38" then determines the distance d_1 in accordance with the specified equation (1) and stores the calculated value in an internal register.

The address control system 37 then calls up the second address of the sample memory 36 and transcribes the second line of the sample list containing the data relative to the second colour specimen into the calculator circuit 38" which then determines and stores the distance d_2. This operation is terminated with the calculation of the distance d_2 appertaining to the n-th colour specimen, and the smallest distance d_{min} is also determined at the same time.

The colour number allocated to the colour specimen having the smallest distance is transcribed from the calculator circuit 38" via the data bus 56, the gate circuit 63 and via the data input terminal 30 into the colour recognition memory 28 and is stored in the same under the address noted.

The address control system 37 then calls up the next address which still remains to be tagged in the colour recognition memory 28, and the actions described are repeated until all the gaps in the colour recognition memory 28 are filled. The result of memory charging is again apparent from Figure 5, wherein a chrominance plane tagged with colour numbers is illustrated as a sectioning surface.

The mode of operation of the circuit arrangement according to Figure 10 is again described in summarised manner with reference to the flow charts in Figures 11 and 12. Figure 11 shows the flow chart for the preloading operation, and Figure 12 shows the corresponding flow chart for the residual charging of the colour recognition memory 28.

The combined memory charging method comprising a preloading action and a residual charging action has the advantage in particular that the calculation period is shortened in the calculator circuit and the entire memory charging operation is thereby performed more quickly.

Figure 13 shows a modified form of the circuit arrangements according to Figures 1, 6 and 10, of which a section only is illustrated.

The transducer stage 18 is followed by another transducer stage 73, in which the Cartesian colour co-ordinates x, y and z are recalculated into the cylindrical colour co-ordinates S, T and L in accordance with the equations:

$$
\begin{aligned}
S &= c_1\sqrt{x^2+y^2} && (S = \text{saturation}) \\
T &= c_2 \arctan \frac{y}{x} && (T = \text{hue}) \qquad (4) \\
L &= c_3 z && (L = \text{brightness})
\end{aligned}
$$

which corresponds to a conversion of the chrominance-luminance colour space into the saturation-hue-brightness colour space.

All the operations described in the foregoing are then performed with the corresponding colour co-ordinates S, T and L.

Thanks to the specified conversion and a corresponding analog/digital conversion in the A/D transducers 19, 20 and 21, it is possible to accomplish a substantially higher degree of resolution in hue than in saturation or brightness. A more precise resolution in the case of lightly saturated colours and a better delimitation

regarding complementary colours, equally become possible. In essence, this is based on the fact that the forming of colour recognition spaces occurs in preferential directions which correspond to the physiological perception of the human eye. The colour recognition spaces are elongated in the direction of saturation and compressed in the direction of hue, thereby allowing of better separation of hues. The elongation and compression of the colour recognition spaces may be enhanced complementarily by selection of the coefficients c_1, c_2 and c_3.

So that fluctuations or shadings within a "grey" may be recognised as a single "grey" colour, a cylindrical or barrel-shaped colour recognition space for "grey" is established around the grey axis. In this case too, the colour space conversion proves to be advantageous since the delimitation of such cylindrical or barrel-shaped colour recognition spaces may be performed more simply with S, T and L colour co-ordinates.

Figure 14 shows a chrominance plane as a sectioning surface through the saturation-hue-brightness colour space. A colour recognition space 272 having the colour number "2" has formed around a specimen colour space element 262. The spheroidal colour recognition space in the chrominance-luminance colour space has been changed by the conversion into the saturation/hue/brightness colour space into an ellipsoid whose longitudinal axis extends in the direction of saturation. A second colour recognition space 273 having the colour number "3" which has the same extension in the direction of saturation as the colour recognition space 272 but is attenuated in the direction of hue, has been formed around the specimen colour space element 263.

Another colour recognition space 271 for "grey" which has allocated to it the colour number "1", was formed around the grey axis, denoted by the point 74.

It is evidently within the scope of the invention to make use of the colour co-ordinates R, G and B or R, G, B colour space, instead of the colour co-ordinates *x*, *y* and *z* or of the colour co-ordinates S, T and L.

The conversions are superfluous in this case, and the output signals of the scanning unit 8 or rather of the logarithmation stage 17 are processed direct.

Figure 15 shows an example of application of the circuit arrangements according to Figures 1, 6 and 10 in the case of a colour scanner for the production of colour separations for textile, decorative and packaging printing.

As already stated in the preamble hereto, the colour to be printed is mixed prior to the printing process and then transferred separately to the print medium, in the printing types referred to. For this reason, the individual colours of the coloured original must be separated by means of the colour scanner, and a separate colour separation must be produced for each colour.

After the procedure specified, the colour recognition memory 28 of the colour scanner is already charged with colour numbers.

The coloured original 1 clamped on a revolving scanning drum 75 is scanned point by point and line by line by the scanning unit 8. The colour co-ordinates *x*, *y* and *z* obtained by scanning the original call the corresponding addresses of the colour recognition memory 28 via the address input terminal 29. The colour numbers stored under the addresses called are read out via the data output terminal 31 and fed to a decoder stage 76. In the decoder stage 76, it is possible to preselect the colour of the original or the colour number for which a colour separation is to be recorded. The colour number selected is converted in a postconnected analog/digital transducer 77 into a control signal S which provides an indication relative to the local distribution of a colour in the coloured original.

The control signal S actuates an electronic switch 78 which retransmits a constant recording signal A_1 (constant write density) generated in an adjustable density emitter 79 to an amplifier 80 when the selected colour appears in the coloured original 1 scanned. An incandescent recording lamp within a recording unit 81 is switched on and off by means of the amplified recording signal A1. The recording lamp causes point-by-point and line-by-line exposure of a record medium in the form of a film 82 which is mounted on an equally revolving recording drum 83. The exposed and developed film is the required line separation.

For recording halftone separations of shaded colours, a "shading" signal A_2 which represents a criterion for the colour saturation or brightness, i.e. for the variation of a colour, may be derived in a "shading" signal transmitter 84 from at least one of the colour measurement signals R, G or B.

For the recording of the halftone separation, the "shading" signal A_2 is retransmitted instead of the constant recording signal A_1, to the recording unit 81 by means of the electronic switch 78. The control signal S then provides the indication regarding the local distribution of a colour in the original, and the corresponding "shading" signal A_2 provides the indication regarding the colour values required for reproduction of the shading.

Prior to recording the separations, the printing result which may be expected may be verified on a colour monitor. In this case, a television camera is followed by the colour recognition memory 28. The television camera scans the coloured original 1 which is to be analysed, and its colour signals call up the corresponding addresses of the colour recognition memory 28. The colour numbers read out control a colour transmitter which allocates a colour signal triplet for operation of a colour monitor to each colour number.

An image memory may again be substituted for the television camera.

For specimen extraction, the coloured original is displayed on a second colour monitor connected direct to the television camera, and the colour specimen is established by means of a cursor and of a measuring circuit.

Figure 16 shows another example of application of the circuit arrangement for colour recognition according to Figure 1 in the case of selective correction in a colour scanner for composite multicolour printing (printing on paper).

The coloured original 1 mounted on the scanning drum 75 is scanned opto-electronically point-by-point and line-by-line by the scanning unit 8 and the colour measurement signals R, G and B obtained at the same time pass via the transducer stage 17 to a first colour correction circuit 85 for a fundamental correction for the forming of initial colour separation Y (yellow), M (magenta), and C (cyan).

The colour measurement signals R, G and B are again converted into secondary colour separation signals Y' M' and C' in a second colour correction circuit 86 for the purpose of selective correction of a particular colour or colour range.

The initial and secondary colour separation signals reach an electronic switch 87 which normally retransmits the initial colour separation signals M, Y and C, and retransmits the corresponding secondary colour separation signals M', Y' and C' to the corresponding amplifiers 80, 80' and 80" only in the case which the colour which is to be corrected selectively appears in the coloured original 1.

The retransmitted and amplified colour separation signals again modulate the brightness of incandescent recording lamps in the recording units 81, 81' and 81". The recording units 81, 81' and 81" causes point-by-point and line-by-line exposure of the films 82, 82' and 82" installed on the revolving recording drum 83. The exposed and developed films are the required corrected "yellow", "magenta" and "cyan" separations.

The control signal S for the electronic switch 87 is generated by means of the circuit system according to Figures 1, 6 or 10. The operative preselects the colour or colour number which is to be corrected selectively, on the decoder stage 76.

During the recording of the separations, it is in each case only the colour number of the preselected colour which is retransmitted by the decoder stage 76 to the post-connected digital/analog transducer 77 and converted into the control signal S for the electronic switch 87.

The decoder stage 76 may be omitted if no more than the colour recognition space for the colour to be selected is programmed in the colour recognition memory 28 by means of the allocating circuit 34.

CLAIMS

1. A method for the recognition of colours, in which a coloured surface is illuminated with light having a known spectrum composition and the intensities of three primary colours are measured opto-electrically in the reflected or transmitted light as colour components, which represent the spatial co-ordinates of the colour locations (points of space) in a colour space, and wherein colour recognition spaces are delimited for each colour to be recognised in the colour space and the measured colour components are verified regarding their correspondence to the colour recognition spaces, wherein, prior to the colour determination for each colour of spatial colour range which is to be recognised, the colour components of at least one characteristic sample dot in the colour or colour range in question are determined and noted, an identification symbol is co-ordinated with each trio of colour components, and the coloured surface is scanned opto-electrically for actual colour determination, the colour components thereby obtained are compared to the colour components noted, and in case of correspondence, the co-ordinated identification symbols are emitted.

2. A method according to claim 1, wherein the same identification symbol is co-ordinated with the colour component trios appertaining to one colour recognition space.

3. A method according to claim 1 or 2, wherein, for forming colour recognition spaces prior to colour determination, sample dots are plotted for the colour component trios possible during the scanning of a colour or colour range which is to be recognised, and identification symbols are co-ordinated to their colour component trios.

4. A method according to claim 1 or 2, wherein the number of the sample dots plotted is smaller in a colour or a colour range which is to be recognised than the number of the colour component triplets of this colour or colour range possible during scanning, and the identification symbols required for forming colour recognition spaces are determined from the colour components of the sample dots and their co-ordinated identification symbols.

5. A method for the recognition of colours in which a coloured surface is illuminated with light having a known spectrum composition and the intensities of three primary colours are measure opto-electrically in the reflected or transmitted light as colour components, which represent the spatial co-ordinates of the colour locations in a colour space, and in which colour recognition spaces are delimited for each colour to be recognised in the colour space and the measured colour components are verified regarding their correspondence to the colour recognition spaces, wherein, prior to the colour determination for each colour or colour range which is to be recognised, the colour components of at least one characteristic sample dot in the colour or colour range in question are determined and noted, an identification symbol is co-ordinated with each colour component triplet of a sample dot, and wherein, for forming colour recognition spaces around the sample colour locations prior to the actual colour determination, each colour locus or colour component triplet which is to be covered is associated with the identification symbol of the sample colours locus lying spatially closest said colour locus in the colour space, the coloured surface is scanned opto-electrically during actual colour determination to obtain colour components, and the identification

symbols co-ordinated with the colour components or colour locations in question are emitted.

6. A method according to claim 5, wherein, in each instance, the spatial distance of a colour locus which is to be covered from all the sample colour locations are calculated and the sample colour locus having the smallest distance is noted, the identification symbol of said sample colour locus noted is co-ordinated with the colour locus which is to be covered, and the colour locus which is to be covered next, is thereupon called.

7. A method according to claim 5 or 6, wherein the particular spatial distance (d) is calculated from the colour components ($a1$, $a2$, $a3$) of a colour locus which is to be covered, and the colour components of a sample colour locus ($b1$, $b2$, $b3$) in accordance with the vectorial equation:

$$d = \sqrt{(a1-b1)^2+(a2-b2)^2+(a3-b3)^2}$$

8. A method according to claim 5, 6 or 7, wherein the most frequently encountered identification symbol among the sample colour locations in question is co-ordinated with a colour locus if the latter is equidistant from several sample colour locations.

9. A method according to any of the preceding claims, wherein the colour space is subdivided into colour space elements (colour locations) by digitalisation of the colour components, the colour space elements have co-ordinated with the storage locations in a first memory (colour recognition memory) which may be addressed via the digitalised colour components of the colour space elements in question, and the identification symbols are stored under the addresses which correspond to their co-ordinated digitalised colour components.

10. A method according to any of claims 5 to 9, wherein a sample list compiled from the colour component triplets obtained during measurement of the sample dots and from the co-ordinated identification symbols is stored in a second memory (sample memory) under consecutive addresses, the colour components or addresses of the storage locations of the first memory which are to be covered are called consecutively and in each case the addresses of the second memory are called between those of the first, the smallest spatial distance and the corresponding identification symbol are determined in each case from the addressed colour components if a storage location which is to be covered and the colour components of the sample list which are read out of the second memory, the identification symbols are stored in the first memory under the addresses called, the colour components obtained during the scanning of the coloured surface are converted into digital form and call the corresponding storage addresses, and the co-ordinated identification symbols are delivered from the first memory.

11. A method according to claim 10, wherein the addresses of the first memory are called line-by-line.

12. A method for the recognition of colours in which a coloured surface is illuminated with light having a known spectrum composition and the intensities of three primary colours in the reflected or transmitted light are measured opto-electrically as colour components, which represent the spatial co-ordinates of the colour locations a colour, space, and in which colour recognition spaces are delimited in the colour space for each colour which is to be recognised and the colour components measured are verified regarding their correspondence to the colour recognition spaces, wherein prior to the colour determination, the colour components of at least one characteristic sample colour locus within the colour or spatial colour range in question are determined and noted for each colour or each colour region which is to be recognised, an identification symbol is co-ordinated with each colour component triplet of a sample colour locus, and wherein, for the purpose of forming colour recognition spaces around the sample colour locations prior to the actual colour determination, the colour locations to be specified by identification symbols, which surround the sample colour locations in shell form, are called shell by shell as the distance increases from the sample colour locations in question, the colour locations called are checked in respect of being marked by identification symbols, the identification symbol of a sample colour locus is allocated to a colour locus called from said sample colour locus, if the colour locus in question has not as yet been allocated an identification symbol, the colour surface is scanned opto-electrically during actual colour determination for obtaining colour components, and the identification symbols previously allocated to the corresponding colour components or colour locations are issued.

13. A method according to claim 12, wherein equidistant shells are in each case laid around the individual sample colour locations, and the corresponding shell having the next greater distance are subsequently formed.

14. A method according to claim 12 or 13, wherein the colour locations which are to be specified within a shell are called consecutively.

15. A method according to claim 12 or 13 or 14, wherein the shells are produced in the form of partial sphere or cubic shells.

16. A method according to any of claims 12 to 15, wherein the colour space is subdivided by digitalisation of the colour components into colour space elements (colour locations) whose position is established in each case by a colour component triplet, and the shells are approximated by corresponding colour space elements.

17. A method according to claim 15, wherein the partial sphere co-ordinates (x_{sm}, y_{sm}, z_{sm}) of all the colour locations playing a part in forming the mth spheroidal shell are derived from the plurality of integers which fulfil the spherical equation

$$m = r^2 = x_{sm}^2 + y_{sm}^2 + z_{sm}^2$$

18. A method according to claim 17, wherein the partial sphere co-ordinates (x_{sm}, y_{sm}, z_{sm}) of all colour locations playing a part informing the mth spheroidal shell are determined by permutation and sign reversal from an ordered co-ordinate triplet fulfilling the spherical equation with the radius $\sqrt{m}$.

19. A method according to any of claims 12 to 18, wherein the partial sphere co-ordinates (x_{sm}, y_{sm}, z_{sm}) with respect to the partial sphere centre of the colour locations forming part of the individual partial spheres (m) are determined, and the colour components (x_i, y_i, z_i) of the colour locations which are to be "documented", with respect to a sample colour locus taken as a partial sphere centre are calculated from the sample co-ordinates (x_{pn}, y_{pn}, z_{pn}) of the sample colour locus (n) in question, in accordance with the equations:

$$x_i = x_{pn} + x_{sm}$$
$$y_i = y_{pn} + y_{sm}$$
$$z_i = z_{pn} + z_{sm}$$

20. A method according to any of claims 12 to 19, wherein the forming of shells is stopped upon reaching a preset distance from a sample colour locus.

21. A method according to claim 20, wherein the distance depends on the number of sample dots plotted in the coloured surface.

22. A method according to any of claims 12 to 19, wherein the forming of the shells is stopped when the colour locations tagged by identification symbols beforehand are encountered at a particular frequency whilst checking the colour locations.

23. A method according to any of claims 12 to 19, wherein the forming of shells is stopped when tangency occurs between the shells of adjacent sample colour locations.

24. A method according to any of claims 12 to 23, wherein the colour space elements (colour locations) have allocated to them storage points of a first memory (colour recognition memory), which are addressable via the digitalised colour components of the colour space elements in question, the identification symbols are stored under the addresses which correspond to their allocated colour components, wherein, prior to colour determination, a sample list compiled from the sample colour component triplets (x_{pn}, y_{pn}, z_{pn}) and the co-ordinated identification symbols in each case, is stored in a second memory (sample memory) and the shell co-ordinates (x_{sm}, y_{sm}, z_{sm}) for the individual shell are stored as a shell list in a third memory (shell memory) under consecutive addresses, the addresses of the second and third memories are called consecutively and the addresses of the storage points of the first memory which are to be tagged by identification symbols are calculated from the sample list and from the shell list, the storage points of the first memory appertaining to the calculated addresses are checked with respect to being tagged with identification symbols and in case of an absence of tagging, the same is or are tagged with the identification symbols of the corresponding samples, the colour components obtained during the scanning of the surface are digitalised and call the corresponding storage addresses of the first memory, and the co-ordinated identification symbols are issued from the first memory.

25. A method for the recognition of colours in which a coloured surface is illuminated with light having a known spectrum composition and the intensities of three primary colours in the reflected or transmitted light are measured opto-electrically as colour components which represent the spatial co-ordinates of the colour locations, within a colour space, and in which colour recognition spaces are delimited in the colour space for each colour which is to be recognised, and the colour components measured are verified regarding their correspondence to the colour recognition spaces, wherein, prior to colour determination, for each colour or spatial colour range which is to be recognised, the colour locus of at least one characteristic sample dot in the colour or colour range in question is determined and noted in the form of colour components, an identification symbol is allocated to each sample colour locus of a sample dot, and wherein, for forming colour recognition spaces around the sample colour locations, the colour locations which surround the sample colour locations in the form of shells are called shell by shell at increasing distance from the sample colour locations in question and are checked regarding being tagged with identification symbols, the identification symbol of a sample colour locus is allocated to a colour locus called from said sample colour locus, if the colour locus in question is not as yet tagged with an identification symbol, the forming of the shells around the sample colour locations is stopped, the colour locations which are not as yet tagged have thereupon allotted to them in each instance the identification symbols of the sample colour locus which is closest spatially within the colour space, and wherein, during actual colour determination, the coloured surface is scanned opto-electrically to obtain colour components and the identification symbols previously allocated to the corresponding colour components or colour locations are issued.

26. A method according to claim 25, wherein, prior to colour determination, a sample list compiled from the colour component triplets (x_{pn}, y_{pn}, z_{pn}) obtained in each case upon plotting the sample dots and from the co-ordinated identification symbols is stored in a second memory (sample memory) and the shell co-ordinates (x_{sm}, y_{sm}, z_{sm}) for the individual shells are stored as a shell list in a third memory (shell memory), both under consecutive addresses, the addresses of the second and third memory are called consecutively and the addresses of the storage points which are to be tagged with identification symbols are calculated

from the sample list and from the shell list, the storage points of the first memory appertaining to the calculated addresses are checked in respect of being tagged with identification symbols and, in the absence of tagging, the same is or are tagged with the identification symbols of the samples in question, and wherein, after stopping the forming of shells, the colour components or addresses of the storage points (colour locations) of the first memory which are still to be tagged are called consecutively and the addresses of the second memory are called between those of the first, the smallest spatial distance and the corresponding identification symbol are determined in each case from the addressed colour components of the storage points which still remain to be tagged and from the sample list read out from the second memory, the identification symbols are stored in the first memory under the addresses called, the colour components obtained during the scanning of the coloured surface are digitalised and call the corresponding storage addresses, and the co-ordinated identification symbols are delivered from the first memory.

27. A method according to any of the preceding claims, wherein, in the case that the totality of spatial colour ranges of the colours available in the coloured surface is restricted as compared to the theoretically possible range of the colour space the colour components or addresses are recalculated for the available address range of the first memory.

28. A method according to any of the preceding claims, wherein the sample dots in the coloured area are plotted by means of opto-electronic transducers.

29. A method according to any of the preceding claims 1 to 27, wherein the coloured surface is displayed on a colour monitor and the sample dots are plotted by means of a cursor.

30. A method according to any of the preceding claims, wherein the colour components are digitalised with different resolution.

31. A method according to any of the preceding claims, wherein the colour components correspond to the trichromatic colour measurement signals (R,G,B).

32. A method according to any of the preceding claims 1 to 30, wherein the colour components correspond to the chrominance signals (x,y) and the brightness signal (z), and the chrominance signals (x,y) and the brightness signal (z) are obtained by co-ordinate conversion of the R,G,B, colour space into the chrominance-luminance colour space.

33. A method according to any of the preceding claims 1 to 30, wherein the colour components correspond to the cylinder colour co-ordinates (S,T,L), and that cylinder colour co-ordinates are obtained by a co-ordinate conversion of the chrominance-luminance colour space into the saturation (S), hue (T), brightness (L) colour space.

34. A method according to claim 33, wherein a cylindrical or barrel-shaped colour recognition space for "grey" is laid around the grey axis of the saturation-hue-brightness colour space.

35. A method according to claim 33 or 34, wherein a colour recognition space in the saturation-hue-brightness colour space is restricted in the direction of the hue by an appropriate co-ordinate conversion.

36. A circuit arrangement for the recognition of colours for carrying out the method according to claim 5, and including a source of light of known spectrum composition for illumination of the coloured surface which is to be examined, and three opto-electronic transducers for detection of the reflected or transmitted intensities of three primary colours as colour components, wherein a colour recognition memory is connected via "A/D" transducers to the opto-electronic transducers and intended for reception of identification symbols, said memory being addressable by means of digitalised colour components, and further comprising an input stage for allocation of identification symbols, a sample memory connected to the input stage and the "A/D" transducers for storage of a sample list compiled from the colour components of the sample dots and the co-ordinated identification symbols, an address control system connected to the colour recognition memory and to the sample memory and intended for calling colour components and for selection of the addresses of the sample memory and of the colour recognition memory, and a calculator circuit connected to the sample memory, the address control system and the colour recognition memory and intended to ascertain the identification symbols from the colour components called and from the sample list.

37. A circuit arrangement for the recognition of colours for carrying out the method according to claim 12, and including a source of light of known spectrum composition for illumination of the coloured surface which is to be examined, and comprising three opto-electronic transducers for determination of the reflected or transmitted intensities of three primary colours as colour components, wherein a colour recognition memory is connected via an "A/D" transducer to the opto-electronic transducers and intended for reception of identification symbols, which is addressable by means of digitalised colour components, and further comprising an input stage for allocation of identification symbols, a sample memory connected to the input stage and to the "A/D" transducers and intended for storing a sample list compiled from the colour components of the sample dots and the co-ordinated identification symbols, a shell memory for storing the shell co-ordinates in the form of a shell list, an address control system connected to the sample memory and the shell memory for calling addresses of said memories, a calculator circuit connected to the sample memory, the shell memory and the colour recognition memory for calculating and calling the addresses of storage locations of the colour recognition memory which are to be tagged by identification symbols and for determining the corresponding identification symbols, and a switching stage for checking the storage locations called in respect of being tagged with identification symbols.

38. A circuit arrangement for the recognition of colours for carrying out the method according to claim 25, and including a source of light of known spectrum composition for illumination of the coloured surface which is to be examined, and comprising three opto-electronic transducers for determination of the reflected or transmitted intensities of three primary colours as colour components, wherein a colour recognition memory is connected via "A/D" transducers to the opto-electronic transducers and intended for reception of identification symbols, which is addressable by means of digitalised colour components, and further comprising an input stage for allocation of identification symbols, a sample memory connected to the input stage and the "A/D" transducers for storing a sample list compiled from the colour components of the sample dots and the co-ordinated identification symbols, a shell memory for storing the shell co-ordinates in the form of a shell list, an address control system connected to the sample memory, the shell memory the colour recognition memory and intended for calling the sample list and the shell list, a calculator circuit connected to the sample memory, the address control system, the shell memory and the colour recognition memory and intended for calculating and calling the addresses of storage locations which are to be tagged with identification symbols of the colour recognition memory and for determining the corresponding identification symbols, and a switching stage for checking the storage locations called regarding being tagged with identification symbols.

39. A circuit arrangement as claimed in claim 36, 37 or 38, wherein a transformation stage for co-ordinate conversion of the R, G, B colour space into the chrominance-luminance colour space is arranged between the opto-electronic transducers and the "A/D" transducers.

40. A circuit arrangement as claimed in claim 39, wherein the transformation stage is followed by another transformation stage for co-ordinate conversion of the chrominance-luminance colour space into the saturation-hue-brightness colour space.

41. Methods for the recognition of colours, substantially as hereinbefore described with reference to the accompanying drawings.

42. Circuit arrangements for the recognition of colours, substantially as hereinbefore described with reference to the accompanying drawings.

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